Towards a skills development theory

J K Shawcross[1]
PhD Student / Head, Executive and Professional Development
University of Cambridge
Cambridge, UK
E-mail: jks45@cam.ac.uk

T W Ridgman
Senior Lecturer
University of Cambridge
Cambridge, UK
E-mail: twr20@cam.ac.uk

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INTRODUCTION

HE Engineering Programmes are required to prepare students for practice and professional work skills are an important component. This paper reports on part of a PhD study [1] (to be published in September 2018) to investigate how work skills can be taught in HE with a focus on preparing students to solve real problems as opposed to academic problems [2].

The research concerns a Masters' level programme containing Short Industrial Placements (SIPs) where pairs of students work on a real and significant problem for a host company. SIPs have been part of the Engineering Education Practice at the University of Cambridge for over 50 years and both the students and host company's value their contribution.

In their Induction module, students are taught a number of key skills and given opportunities to practice and integrate them before undertaking their first SIP. These include: solving a range of industrial problems using a systematic evidence based approach, presenting analysis and recommendations to senior company audiences and working in a small group under significant time pressure. This skills teaching was judged to be effective as students on previous programmes had been able to solve real problems in their first SIP. This contrasts with the common perception that HE does not adequately prepare students for practice.

[1] Corresponding Author
J K Shawcross
jks45@cam.ac.uk

An Engaged Scholarship approach [3] was adopted to study this anomaly to investigate any implications for theory [4]. There are four research activities in each Engaged Scholarship cycle: Problem Formulation, Theory Building, Research Design and Problem Solving. This paper focusses on the Theory Building research activity where a potential skills development theory was constructed. Whilst a summary of the other three research activities is provided, the constraint on paper length does not allow for sufficient detail regarding the literature review, research methods and results required of a research paper. This paper is positioned as a concept paper to promote discussion and debate.

1 PROBLEM FORMULATION

This research activity requires a systematic and detailed investigation of the area of study from both a practice and academic perspective to understand its multiple dimensions. From a practice perspective, there were two main findings; SIP skills were developed through five facilitated HE class-room based experiences that simulated solving real problems in a work context even though the description of SIP skills was limited. An analysis of literature identified a gap related to a general level teaching model related specifically to developing skills in HE. Three significant theories: Constructive Alignment (CA) [5], Experiential Learning (EL) [6] and Self-Efficacy (SE) [7] were found to align well with the skills teaching in the Induction module and applying CA to the teaching practice revealed perfect alignment between the learning activity and the formative assessment, providing one explanation of why the practice was effective.

It was concluded that a first-hand view of the five simulated experiences was necessary to deepen understanding of the practice and the research question identified was “What happens during the five experiences and supporting lecture session to support the development of SIP skills?”

2 THEORY BUILDING

The theory building Engaged Scholarship activity develops a plausible theoretical lens that can support the answering of the research question and is closely linked to the previous problem formulation activities requiring a deep familiarity with the problem domain [3]. Three activities are involved: creating, constructing and justifying a theory [3].

2.1 Creating the theory

Creating a theory uses an abductive reasoning process, trigged by an anomaly, to select a plausible solution that might resolve the anomaly [3].

In this case, the anomaly was the successful SIP skills development practice in the Induction Module because it produced results that contradicted the prevalent view that HEI’s are not adequately preparing students for work. Drawing on the problem formulation work above, a plausible explanation of how SIP skills are developed, was ‘*multiple work-relevant experiences, appropriately facilitated/taught and related to a specific set of work skills enables students to learn these skills and subsequently deploy them in practice’*. This has the potential to become a Skills Development Theory (SDT).

2.2 Constructing the theory

Constructing a theory uses a logical deductive reasoning process to identify concepts or events, the relationships between them, the associated the boundary conditions, and the reasons for the relationships (Bacharach 1989). Taking the ‘potential theory’ above, there are three high level concepts: work-relevant experience, appropriate facilitation/teaching and a specific set of work skills.

From the problem formulation activities, the three main theories that contribute to skill development are Experiential Learning (EL), Constructive Alignment (CA) and Self-efficacy (SE). How these theories relate to each other is explored first.

The 3P Model of Teaching and Learning [8] shown in Figure 1 was the preferred model of CA because it identified a broader range of concepts and the relationships between them than other versions of the constructive alignment model [5, 8] which focussed on curriculum objectives, teaching/learning activities and assessment tasks.

The authors propose that both EL and SE can be nested within CA and the case for this is presented below. An EL review [6] found that EL involved the following components;

- an ‘active’ doing phase or **experience** that forms the material of learning that is not usually taught
- **reflection** – either deliberately or not deliberatively
- a mechanism for **feedback**
- a formal **intention to learn**

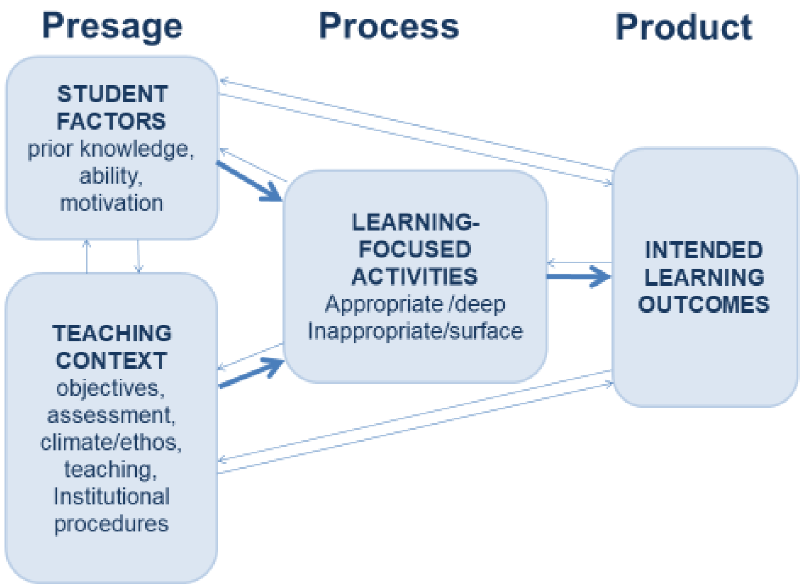

Figure 1: 3P Model of Teaching and Learning

An **experience** with **reflection** and **feedback** was seen to fall within the ‘Learning-Focussed Activities’ box of the 3P model and the formal **intention to learn** connected with student motivation in the ‘Student Factors’ box.

Bandura suggests four methods for supporting the development of self-efficacy [7]: mastery experiences, vicarious experiences, social persuasion and enhancing physical and emotional states. The mastery and vicarious experiences are considered to fall into the ‘Learning Focused Activities’ box, with social persuasion relating to student motivation and creating a positive mood related to the climate/ethos aspects in the ‘Teaching Context’ box.

Having established how EL, SE and CA relate, the connections between the proposed theory, see section 2.1, and CA are compared. The ‘multiple’ aspect of experiences is not explicitly captured in the 3P Model. To include the components of EL, SE and build in the 'multiple' experiences the CA model needs adapting to work at a more detailed level and focus on skills.

Adjusting the CA Model an initial representation of this skill development theory is shown in Figure 2. 'Multiple' cycles was stressed by adding a specific note. Such cycles are considered to encompass all components of CA as the teaching objectives and associated Intended Learning Outcomes (ILOs) should progress through each cycle as the specific skill set develops. The components of EL and SE are not currently represented and can be added to the 'Learning-Focussed Activities' box. At this more detailed level, from a teaching perspective there are a number of 'givens' that a teacher cannot directly influence when teaching skills – these being student prior knowledge, ability and institutional procedures.

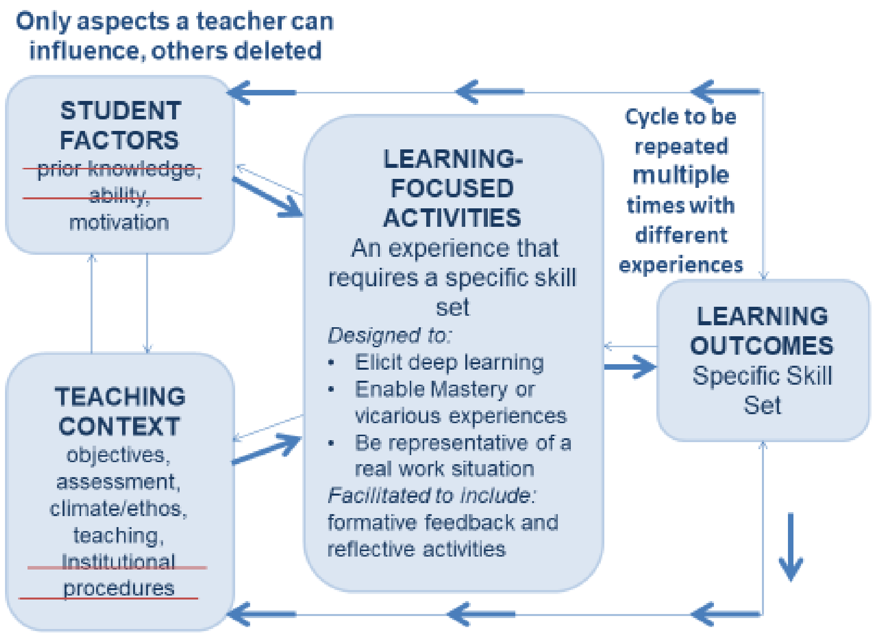

Figure 2: Conceptual Skill Development Model - Initial Representation

The Conceptual Skill Development Model above was refined, see Figure 3, based on the rationale below. In Figure 2, the 'Learning-Focussed Activities' box is now significantly expanded and would benefit from being split to emphasise the different types of components. Two categories emerge: providing experiences relevant to practice and supporting learning from experience. Both these categories encourage a deep learning approach as they incorporate a range of higher level cognitive activities [5].

The original 'Teaching Context' box was renamed 'Create a learning environment to encourage deep learning' to incorporate other aspects that influence a deep learning approach such as assessment [5]. Motivation was moved from the 'Student Factors' box and included as something the teacher can stimulate by making the case to the students that the skills to be learnt are both relevant and important. This eliminates the need for a Students Factors box in Figure 3 as the other two aspects were deleted, as not being something a teacher could influence – see Figure 2.

One aspect of the original 'Teaching Context' box was objectives. Given the problems identified during the problem formulation on defining skills, combined with the need to define both objectives for the series of multiple experiences as well as each individual experience, it is proposed to treat this as a separate box: 'Describe skills'.

The logic links remain those in the CA model with the bold arrows indicating the main direction of flow and emphasising a repeated application. Returning to the proposed theory: *multiple work-relevant experiences, appropriately facilitated/taught and related to a specific set of work skills enables students to learn these skills and subsequently deploy these in practice*, and comparing this to Figure 3, it can be seen that;

- work relevant experiences are part of C,
- appropriately facilitated/taught has aspects in parts of A, B, C and D
- work skills are captured in A and also in E.

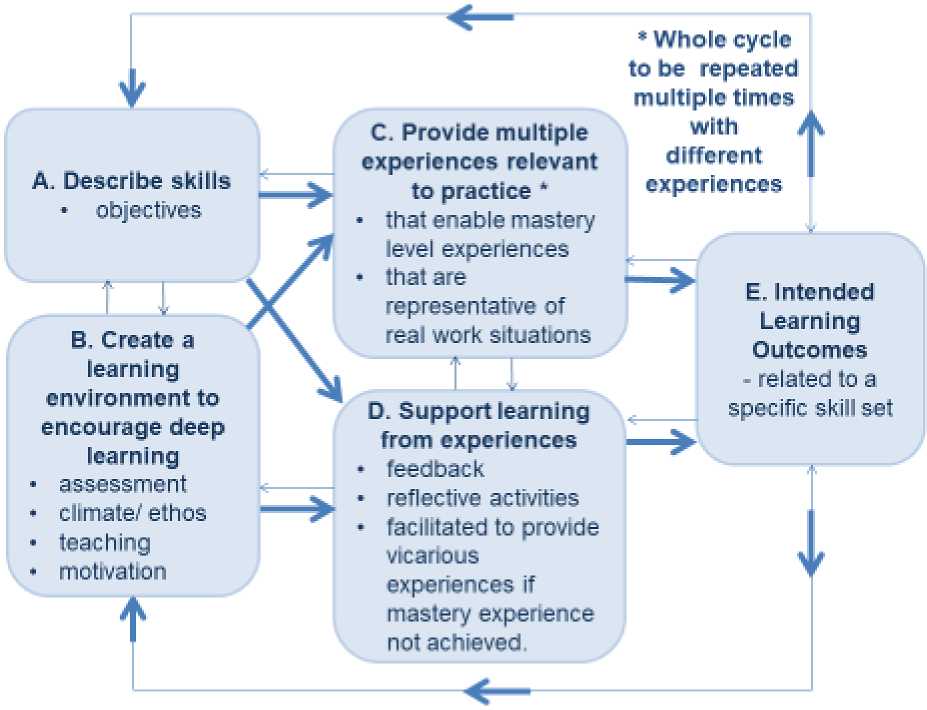

Figure 3. Refined Conceptual Skill Development Model

In conclusion, there would appear to be a reasonable fit between the proposed theory and conceptual skill development model constructed.

The final aspect of constructing a theory is stating the boundary conditions or limits at which the theory is expected to work. At this formative stage, the most limiting activity was likely to be providing experiences relevant to practice, as a HE environment may not be representative of a practice environment and a HE teacher may not have sufficient understanding of appropriate practice activities. Another boundary will be the minimum number of experiences required to create the intended learning outcomes. This is unlikely to be the same for all skill sets, as more complex skill sets will probably require more experiences. It is anticipated that the number of experiences would be determined through practice.

2.3 Justifying the theory

Justifying a nascent theory is the final part of the theory building process [3] and it is necessary on both an empirical and a conceptual basis. Inductive reasoning is used to test the fit with the world on an empirical basis and rhetorical arguments to persuade on a conceptual basis.

On an empirical basis, no evidence was found to contradict the theory. On a conceptual basis the credibility of the new theory was strong as it was based on the established Constructive Alignment theory in which two further well established theories were integrated. As none of the three contributing theories were logically compromised in this integration, it was deduced that the new theory was also logically valid. Validity is the main criteria for the ES theory building stage [3]. With this seemingly achieved the new skill development theory required conversion into a format suitable for testing.

The new theory is represented as a system model that highlights the complex nature of skill development. This model was translated into a simpler analysable format, a conceptual skill development framework, for testing the theory.

3 RESEARCH DESIGN & EXECUTION

This research activity selects a research design and then executes it to answer the identified research question i.e. “What happens during the five experiences and supporting lecture session to support the development of SIP skills?”

3.1 Research Design

A variance research design was selected as this would enable the practice to be compared with the derived theoretical framework. Engaged Scholarship employs a mixed methods research strategy and the methods employed were selected on merit [9]. A non-participant observation strategy was selected to compare the teaching practice with the theoretical framework because the observer was an experienced University teacher. Questionnaires were used to collect information from the students on what they thought helped them to learn skills as this was the only practical method in the time available.

There was a firm belief amongst the Induction Module staff that the five simulated experiences were responsible for the development of the students’ SIP skills. However, as limited evidence was available to substantiate this claim, the assumption that students had low levels of SIP skills on starting the programme required testing because, if this was not the case the theory would not be valid. As a method of empirically testing their SIP skill levels was not available, an alternative strategy of finding a proxy as an indicator was adopted. Students prior experiences such as business plan projects and relevant work experience was captured via a questionnaire to provide an evidence-based indicator.

Full details of undertaking this research are available in the PhD thesis [1]

3.2 Research Results

The comparison of the practice to the theoretical framework enabled some preliminary testing of the SDT to be undertaken. The many connections observed between aspects of the conceptual skills development framework reinforced the view that skill development is an interlinked system and a systems model view is an appropriate way to represent this.

Of the four high level components (see Figure 3) that combine to enable the intended learning outcomes to be achieved, C - multiple experiences and D - supporting learning from them, were seen to be directly responsible for teaching skills. Components A – describing skills and B – learning environment were seen to be essential enablers.

All aspects of the theoretical framework were recognised as part of the teaching practice and two further aspects were identified.

Overall, the SDT was found to be promising. The skills development practice, despite a poor definition of SIP skills and weak reflection activities was still effective as the combination of multiple, constructively aligned, relevant experiences enabled the students to learn SIP skills.

The student view on what they thought helped them to learn skills provided sufficient evidence that their understanding of skills and skill development was lower than expected. This indicated that the student factors of ability and prior knowledge, eliminated from the SDT earlier require reinstating and reinforce the connectedness of teaching and learning, overlooked earlier in the pursuit of a teaching perspective.

Analysis of the data on students' previous experience revealed little exposure to opportunities that would enable them to solve real industrial problems. It was concluded that the majority of students at the start of the programme had low levels of SIP skills, thus indicating that the experiences in Induction were largely responsible for developing these skills.

4 PROBLEM SOLVING

This final Engaged Scholarship research activity involves communicating and interpreting the findings with the intended audience. The work summarised in this paper has been presented and defended as part of a PhD thesis. This paper is intended to share the findings with a wider Engineering Education audience and engage in debate on the implications.

The conclusions from the research summarised above are that the proposed Skills Development Theory is promising, the model requires further refinement and testing, and the student factors previously removed reinstating. This results in a preliminary skills development model shown below in Figure 4.

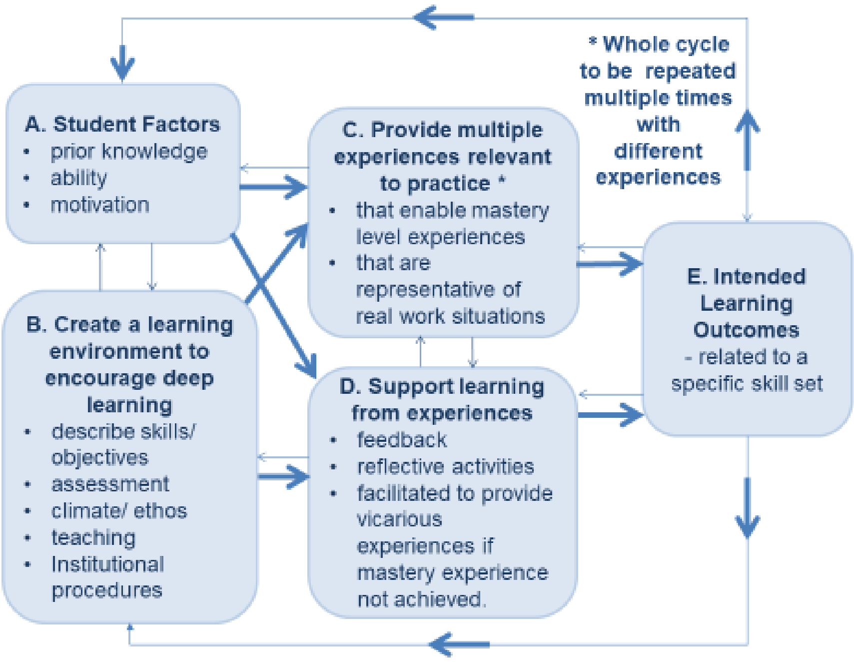

Figure 4. Preliminary Skill Development Model

Further work is required to refine the definition and description of each aspect of this model and determine if and how other aspects should be included. Other work from this PhD study has focussed on describing skills which requires integration. It would also be interesting to investigate the typical number of different exercises required to become sufficiently proficient for different skills. This will depend on many factors: the range of representative problems to be experienced prior to real-world practice, the diversity of contexts in which they happen, the complexity of the work involved, the level of resource available and the abilities of the students.

This model remains at a high level and provides a holistic perspective. Alternative views, such as a process view would be helpful in describing the activities that Engineering Educators would have to undertake to be able to apply this in practice.

5 IMPLICATIONS FOR TEACHING AND LEARNING

The Preliminary Skills Development Model demonstrates that teaching skills is significantly different to teaching knowledge because of the different nature of the activities involved in the process. Designing simulated experiences that are relevant and authentic, facilitating mastery and vicarious experiences, as well as providing timely reflection tasks are all examples of activities not often associated with teaching knowledge using traditional lecturing approaches.

Engineering Educators need to be trained on how to do these activities and those aspects most likely to be new include:

- developing a good understanding of what the graduates are actually expected to do in practice in industry and across a range of different sectors
- designing and testing simulated experiences
- skill development facilitation skills

This is a big ask of already busy teaching staff and not easily undertaken without significant Institutional investment in such an approach. Developing a team approach, drawing on specialist expertise and experience from both industry and educational designers is just one way that this could practically be achieved.

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